PUBLIC HEALTH IMPLICATIONS OF AIRBORNE INFECTION: MEDICAL ASPECTS

ALEXANDER D. LANGMUIR

Epidemiology Branch, Communicable Disease Center, U. S. Public Health Service, Department of Health, Education, and Welfare, Atlanta, Georgia

In an effort to treat the subject of the control of airborne infection in some systematic manner, one turns logically to Theobald Smith's concept of the chain of infection (6). There are four links to his chain. In order to survive, a parasitic microorganism must enter the tissues, multiply, find exit, and be transferred.

Specific control measures may be applied to break or at least to weaken one or more of these links. For example, the wearing of an effective mask should prevent entry. Artificial immunity or chemoprophylaxis is designed to prevent multiplication. Masks or even the proper use of handkerchiefs are designed to prevent exit. The techniques of air sanitation (controlled ventilation, ultraviolet irradiation, disinfectant vapors, and dust suppression) have been developed to reduce transfer of infectious agents through the air.

This classic approach to the public health aspects of control does not, however, take into account in an adequate way the precise understanding that has developed in recent years of three considerations:

1) The importance of the exact location of portals of entry in the respiratory tract.

2) The remarkable relation between doses and particle size of the infecting aerosol.

3) The extraordinary filtration capacity of the mammalian lung.

Also, the simple concept of the chain of infection applies directly only for those diseases where man is an intrinsic part of the survival mechanism. The infection chain becomes more complex when the infections having sources in nature are concerned. Elimination of these sources then becomes an additional approach to control of the human disease.

Since much of our knowledge of airborne infection is now on a sound theoretical basis, it is possible to consider approaches to control in precise and specific ways. Several examples will be discussed.

Psittacosis. The problem of psittacosis acquired from parakeets and other psittacine pets is a small and widely diffused one. In the range of 100 cases a year are reported in the United States. Control of the problem logically should be directed at the source. The maintenance of sanitary breeding establishments, the sound economics of breeding infection-free birds, the proper handling of birds in transit, and the judicious use of antibiotics in feed seem most promising.

Psittacosis associated with poultry, so far, seems to be of relatively minor importance except as a sharply localized industrial hygiene problem. The control of infection at the sources, namely, in chicken, turkey, and other poultry flocks in the country, may be quite difficult and does not seem economical. The first step in preventing the occasional sharp outbreaks in poultry-processing plants should be the development of better facilities for the protection of the workers. The exact sources of the infective aerosols, particularly the fine particles, need further elucidation. Certain specific processes on the slaughtering-dressing line may be largely or solely responsible. These processes might be changed or hoods and controlled air currents might be used to keep the infection from the employee.

Brucellosis. Occupational brucellosis has many similarities to industrial psittacosis. Control of the source, largely swine, is a major national undertaking that hopefully can succeed over a period of years; but, in the meantime, control of the processing plant seems most logical. Some of the slaughtering practices may be so messy and intrinsically productive of infective aerosols that the employment of immunes rather than susceptibles may be the most practical temporary solution.

Anthrax. For years, the British have attempted to control industrial anthrax with partial success by washing and disinfecting contaminated wool and goat hair at a central station in Liverpool. Such a program would not be economical in this country, nor does the seriousness of the problem warrant such steps. An effective vaccine has been developed which, along with employee education and appropriate industrial medical services, should eliminate the problem in the wool, hair, and related industries. The few agricultural cases and the occasional sporadic case that is not directly traceable to a known source will remain a small problem with no easy solution in sight.

Q fever. The comprehensive and systematic studies of Lennette and his co-workers illustrate well the degree to which carefully conceived quantitative studies can delineate exact sources and natural mechanisms of aerosol production. The pregnant ewe and the act of parturition are clearly of primary importance in the spread of this infection (9). Thus, the time and place to apply control measures have been precisely identified.

The outbreak of Q fever traced to a rendering plant in the San Francisco Bay area presents a different, though related problem. Presumably, the aerosol that spread for miles downwind had its origin from an infected ewe or infected genitalia that had been rendered. The simple solution here might be to prohibit the rendering of sheep and goats and their organs, but a more imaginative solution would be first to find the possibly single step in the rendering process that generates small-particle aerosols and then to appropriately modify only this step.

Pulmonary mycoses. Coccidioidomycosis and histoplasmosis pose the great problem of widely distributed natural sources of infective spores. Control of these fungal infections seems to be as difficult as control of ragweed pollen, but the concept of elimination of the source should not be abandoned. As more epidemics are studied and more is learned about the circumstances permitting the growth of *Histoplasma capsulatum* in nature, the more localized the sources appear to be. Once they can be clearly delineated, then methods to prevent growth or perhaps to prevent sporulation of small particles can be sought. For example, old chicken houses are a notorious focus of histoplasma spores. Simple changes in poultry practices such as the liberal use of lime or acid phosphate or other useful fertilizer could be promoted economically if they were shown to be useful. If starling roosts are an important source of histoplasma spores, it should not be too difficult to devise ways to modify the ground under these roosts to prevent further multiplication and dissemination of the fungus.

With regard to coccidioidomycosis, knowledge of the natural sources of the fungus is not as far advanced as it is for histoplasmosis. Certainly, there is some degree of localization of these sources in nature and some variation in growth of the fungus with season and rainfall. More understanding of the native habitat and microecology of *Coccidioides immitis* might make less staggering what now seems an insuperable task.

Pulmonary tuberculosis. The work of Wells (8), Lurie (4), and Riley (5) and their colleagues has brought into sharp focus the airborne mechanisms in primary pulmonary tuberculosis. The formerly almost universally accepted concept that tuberculous infection resulted from prolonged intimate contact is rapidly giving way to the new concept of the inhalation of a single small particle. The former view is vague and calls for some sort of cumulative effect or poorly defined threshold phenomenon. The new view is precise and permits a clear visualization of the process of infection.

The implications of the airborne theory of tuberculosis are radical. Opportunity for infection must be an exceptionally rare event. A large majority of our young adults have not yet become infected, including even medical students, nurses, and family contacts of sputum-positive cases. At the same time, there are a number of well-described epidemics of tuberculosis in which 90% or more of the exposed group became infected over a very short period of time. Gedde-Dahl (2) describes an epidemic that must have been induced during the course of a Christmas tree festivity in a small school room. Therefore, under certain highly specialized circumstances some cases can be highly infectious. Logically these dangerous spreaders are those who create infective aerosols of very fine particles, essentially single or a very few tubercle bacilli.

The classical approach to tuberculosis control has been the detection, isolation, and treatment of open cases. Special attention is devoted quite properly to sputum-positive cases, but little attention has been given the concept that probably a very small proportion of sputum-positive cases act as dangerous spreaders. More study should be directed toward the detection of such dangerous spreaders and the definition of the circumstances that determine their unique capabilities.

For example, the tenacious mucoid sputum containing large clumps of tubercle bacilli probably does not readily yield fine-particle infective aerosols, whereas a watery sputum containing more dispersed organisms should do so more easily. The normal act of coughing and expectoration probably yields large droplets, whereas the more forceful act of sneezing is likely to fragment sputum into smaller droplets. The act of singing by an open case of tuberculosis may well produce even finer particles. It should be noted that group singing is specifically mentioned as having occurred in several of the known epidemics of tuberculosis (2, 3, 7).

Further study of dangerous spreaders is possible through a continuation of the meticulous experimental studies of Riley and also through more intensive and directed investigation of epidemics as they occur in the field. Now that children and young adults are largely tuberculin negative, the liberal use of periodic tuberculin testing should be employed on a wide scale not only to detect and promptly isolate dangerous spreaders but to provide the opportunity to study them to learn the essential features determining their dangerousness.

No discussion of public health aspects of a subject such as this should close without some attempt to look toward the future. It is evident that airborne infection is now recognized as having considerably more importance than was appreciated 10 to 15 years ago. Also, its underlying mechanisms are better understood. It is quite probable that new airborne infection problems will arise that are not now appreciated. An example of this might be infectious hepatitis. Certain sharp epidemics of this disease have been described that have all the characteristics of a common source and origin in a single exposure, but the usual common sources such as water or food have been quite adequately excluded (1). One wonders indeed if such epidemics could have been airborne.

Finally, it is almost axiomatic that with the rapidly increasing pace of living, with greater crowding and interchange among people, and with more automatic devices, including air conditioning, new and unanticipated disease problems will arise. Those concerned with the public health must endeavor to anticipate, identify, and eliminate these hazards when possible or to recognize their existence promptly when they fail to prevent their occurrence. In the broad group of as yet unidentified future problems, the mechanisms of airborne infection may loom large.

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